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WAR MEDICINE AND SURGERY

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AMPUTATIONS IN WARTIME.

It is estimated that more than half a million amputations were carried out during the Great War. The full benefit of the experience gained from these operations, however, did not become available immediately. It was easy enough to assess such factors as the mortality rate under the prevailing conditions, but it was not possible to predict how efficient the artificial limb would be, and how often complications would arise. These things could be found out only by a painstaking follow-up of the patients treated. It was not until 1927 that the surgeons of the Ministry of Pensions in England decided that operations such as Syme's, which produce an end-bearing stump, should no longer be done in hospitals under their control. In 1941, Canadian surgeons working for the Department of Pensions and National Health were still gathering evidence which made them oppose these conclusions and write spiritedly in favour of Syme's operation.[3]

It is therefore obvious that the technique for amputations will not be quickly altered by the experience gained in the present war. By studying recent literature we can learn of such things as the effect of sulphonamides in making more amputations possible, and the surgical facilities available for performing the operation under the conditions of modern war, but the work is mostly planned on the basis of investigations begun at least as far back as the Great War.

Indications for Amputation.

There are four indications for amputation which are specially important in wartime: (*a*) loss of blood supply; (*b*) massive gas gangrene; (*c*) severe pyogenic infection; and (*d*) a severely mangled limb.

Trauma may produce such destruction of the blood vessels that gangrene is imminent and immediate amputation required. Arteries are most likely to be damaged in parts where they are relatively fixed. For example, the femoral artery is specially vulnerable as it passes through the *adductor magnus* muscle. Again, if the interosseous membrane between the tibia and fibula is pierced, there is almost always some vascular damage; the area becomes swollen and tense and there is progressive interference with the blood supply of the distal parts. Cases have also been reported from the present war in which the loss of blood supply was due to a forgotten tourniquet; in one instance a tourniquet was applied in the field and left on for nineteen hours.

Localized gas gangrene can be treated by excision of the affected muscle, but amputation is essential when several muscle groups are involved or when the gas gangrene is associated with a compound fracture or an injury of the main blood vessel.

Many severe pyogenic infections are cured by conservative treatment, but sometimes, especially in the case of suppurative arthritis or infected compound fracture, the condition runs a chronic course, and the patient's life may be threatened by severe toxæmia or secondary hæmorrhage. The decision about amputation is a difficult one to make, especially if the site for the operation is the upper limb or upper part of the thigh. Even successful interference in these cases brings about serious loss of function, but non-interference may result in death. Very little definite help can be given to the surgeon in his attempt to pick those patients who will die unless operated on; he has to assess the patient's progress by studying such factors as temperature, pulse rate, appetite, body wasting, hæmoglobin value and leucocyte count.

In cases of mangled limb there may be an almost complete traumatic amputation and it is obvious that the remaining threads of tissue should be severed. In general, however, one should be very conservative about amputating a crushed limb; such an operation is necessary, in the early stages, only if the blood supply is destroyed. A relatively frequent type of wartime injury is comminution of the hand produced by the premature explosion of a hand grenade or "egg bomb". The more severely the hand is injured, the more important is it to preserve such useful structures as remain; even loose tags of skin may be valuable for subsequent plastic operations.[5] It is generally a sound principle to save all you can of a mutilated hand. There are only two modifications of this rule: (*a*) where the injury is localized, say, to a finger, the crippled member may be a nuisance that had better be removed; and (*b*) the surgeon should always aim at restoring the maximum amount of function, and in some cases this is not achieved by retaining the maximum amount of tissue; for example, in the case of a finger, disarticulation at a metacarpo-phalangeal joint is better than preserving a small stump of the first phalanx. This is not true of the thumb. Here there are different functional requirements and even a short stump of the first phalanx may be useful.

As far as possible the surgeon should obtain the opinion of an experienced colleague before amputating a limb. In general, there should be more conservatism towards removing the upper limb than towards amputation of the lower extremity. An artificial upper limb is almost useless, but shortening of the limb produced by treatment is not a handicap. It is fortunate that conservative treatment is often possible in wounds of the upper extremity: the patient is not very liable to such complications as shock, gas gangrene or irreparable damage to the main artery.

Methods of Amputation.

Methods of amputation suitable for war conditions can be classified in the following way:[4]

1. Guillotine method: (*a*) circular or flapless type, (*b*) modified operation using flaps of skin and subcutaneous tissue.
2. Repair of guillotine stump: (*a*) plastic closure, (*b*) plastic resection, (*c*) reamputation.
3. Flap amputation at site of election.

Circular Method.

A true guillotine amputation is one in which skin, muscles and bone are divided in the same plane, but such

an operation is scarcely ever practised. The term "circular guillotine" is used for the operation that is usually done. The skin is cut through by an incision which encircles the limb; it is then retracted, and the fascia is cut at the level of the retracted skin; a similar process is repeated with the various layers of muscle; the periosteum is then incised and the bone finally sawn through. Care should be taken about the periosteum; if a cuff of it is removed altogether, the blood supply of the underlying bone is reduced and infection is likely; if it is displaced, spurs of bone are formed by the scattered subperiosteal cells.

A long amputation knife is the best instrument for cutting through the muscles. As the operation often has to be done under conditions of emergency, when some degree of shock is present, the amount of hæmorrhage may be surprisingly small; but large vessels are doubly tied with silk, linen or cotton, and muscle bleeders are transfixed with a fine suture. It is better to dispense with a tourniquet if hæmorrhage can be controlled without it. It is now becoming accepted that nerves should neither be pulled down nor crushed, since this added trauma is harmful. Although speed for the sake of speed has long been condemned in operative surgery, this operation is an emergency measure and should be done quickly. In the days when amputations were the major part of military surgery, remarkable speed was developed. Larrey, surgeon to Napoleon, performed more than 200 amputations in one day.

At the end of the operation the surgeon applies a dressing such as *tulle gras*, which is non-adherent and permits the escape of discharges; this dressing remains undisturbed for a week or two at a time. Sulphonamides may be used locally as a prophylactic measure. It is very important to avoid frequent changes of dressing and to take all possible precautions against cross-infection from medical staff, nursing staff and patients.

Traction is applied to the skin of the stump within twenty-four to forty-eight hours; otherwise the muscles and overlying skin contract and healing becomes impossible. Four strips of adhesive strapping are spaced at intervals around the stump and secured by two or more encircling pieces. Traction is exerted on the distal six inches of skin and the strips are attached to within one inch of the wound edge. The strips used on an average thigh would be about two and a half inches wide. The free ends are connected to a spreader, and from this a cord passes over a pulley to a bag containing a weight of about five pounds. There are various alternatives to this method: for example, stockinet glued to the skin may be used instead of adhesive, or fixed traction by means of a truncated Thomas splint may be used instead of the movable traction. The important thing is that traction should be kept up until it gradually draws the elastic skin down over the granulating surface and allows the wound to heal. If infection occurs it should be treated by irrigation with sodium hypochlorite and the local use and oral administration of sulphonamide.

The guillotine operation should always be done at the lowest level possible. The site is obvious if the operation is carried out because of trauma, but it is not so easy to decide the lowest level consistent with the total removal of an infected area. Disarticulation at a joint is comparable to a guillotine amputation, and some surgeons in this war have preferred to disarticulate at the knee joint rather than amputate through the lower part of the thigh, when giving preliminary treatment for an injured leg. They claim that this facilitates secondary amputation in the thigh. It is a general principle that guillotine amputation should rarely be done at the site of election for final amputation. It cannot be assumed that the guillotine amputation is the final amputation; if it is not, any further operation has to be done above the optimal site. There are some instances, however, in which it is impossible to follow this rule; for example, if only seven inches of femur can be conserved, and the skin below is so damaged as to be unsuitable for flaps, then a guillotine operation has to be done; but special attention must be paid to skin traction in these patients so that the full seven inches of bone length is retained.

The guillotine method is not an ideal type of amputation, but it is simple and rapid, it gives perfect drainage, and it permits only a minimum exposure of tissue. The indications for it are as follows.[3]

1. It is used when amputation is required in a patient who is unlikely to survive anything more than a quick and simple operation. Such patients are frequently seen in wartime, for large numbers of casualties tax both the ambulance and the medical services, and treatment of some of the wounded is inevitably delayed.

2. It is used when amputation is required for severe sepsis. The guillotine operation gives the smallest possible wound and provides excellent drainage; shock is minimal. It is likely that reamputation will have to be done later at a higher level when the stump has become clean and the patient's general condition is better. The operation is therefore an unsuitable treatment unless it can be carried out below a site of election for final amputation.

3. It may be used when amputation has to be done at the site of election and no skin is available below that level for flaps. In this case there must, however, be reason to hope that the wound will heal cleanly.

4. When a person has been caught by a limb in machinery or pinned down by falling masonry, the guillotine amputation is recommended because of its simplicity.

The guillotine operation has been roundly criticized. Ogilvie describes it as "a crime which no conceivable surgical or military circumstance can justify". His criticisms are accepted to the extent that, wherever possible, the operation is modified by fashioning simple flaps of skin and subcutaneous tissue. It is also recognized that careful after-treatment is needed to make the guillotine amputation a success: if the raw area is repeatedly dressed, pain and loss of fluid result, and the chances of cross-infection are increased; if skin traction is not applied, the skin and muscles retract and a conical stump with projecting bare bone results; if faulty posture is allowed during the rather long period of waiting for an artificial limb, there may be some permanent loss of joint movement.

It has been claimed that the guillotine amputation has no advantage in the treatment of gas gangrene, since the infection travels proximally in muscle rather than skin, and, therefore, any muscle which may safely be left may also be safely covered with skin flaps.

Modified Guillotine Amputation.

The best dressing for amputated muscle and bone is skin, and the classical guillotine is often modified to include skin flaps. It must be emphasized that muscle should not be included in the flaps, for it permits the upward spread of pyogenic infection and gas gangrene and neutralizes the advantages of the guillotine amputation.

The modified guillotine method has been used successfully in the present war. The flaps must be left unsutured for thirty-six to forty-eight hours, after which, if the stump is clean, they may be drawn together with a few loose sutures. There is usually sufficient skin available to make the modified method possible. The surgeon is often able to close the wound subsequently and obtain a satisfactory stump without further operation.

This operation overcomes the problem of skin retraction, which is such a troublesome feature of the classical technique. It also meets the case when an amputation giving good drainage is required through a site of election. It retains the chief advantages of the original operation in that adequate drainage is provided and fascial planes are not exposed.

Repair of Guillotine Stump by Plastic Closure.

If a guillotine amputation is performed, a subsequent reamputation is not always necessary; on the contrary, many guillotine stumps, if treated with proper skin traction, ultimately heal with a terminal scar, and can be satisfactorily fitted with an artificial limb. This does not often occur with amputations of the leg, but is true of those of the thigh, arm and forearm. The healing may be hastened if a minor operation for the plastic closure

of the skin is carried out. This should not be done until the following evidence has shown that infection has subsided: absence of œdema, absence of pathogenic organisms on culture, and absence of radiographic evidence of bone infection or sequestration. The operation itself is simple: the scar tissue is excised, the skin is undercut from the fascia, and the skin is sutured. The muscle and fascia have become fixed to the stump end and do not require suture. This would not be true if secondary closure were attempted soon after the operation; secondary closure involves further shortening of the bone in order to bring the skin, fascia and muscle together, and is therefore rarely attempted.

Plastic closure is not required if it is intended to perform a permanent amputation through a more proximal part subsequently. Closure of the wound is very important, however, in those cases in which the stump is rather short and has to be conserved. A longer stump can be secured by a guillotine amputation with plastic closure than by a primary flap amputation, if the skin is not viable below the level at which the bone has to be divided.

Repair of Guillotine Stump by Plastic Resection.

Sometimes skin traction may not be properly carried out, either through lack of facilities, lack of knowledge of its importance, or inadequacy of technique. As a result, the soft tissues retract and the bone end may extend for a few inches beyond the retracted skin. The operation for repair of the stump in these cases must include bone shortening. The scar is excised, the bone is shortened, and the wound is then closed.

Reamputation of Guillotine Stump.

The guillotine operation is often done as a temporary expedient, to be followed by a flap amputation at the site of election when the opportunity occurs. If reamputation is done too early, latent sepsis may be activated. The surgeon must wait until the wound is covered with healthy granulations, and there is no œdema of the stump, no tenderness on pressure, and no radiographic sign of periostitis. Even after the stump has apparently healed, the patient should be allowed several weeks of activity on crutches and a break from hospital life before the reamputation is carried out. It is reasonable to allow a period of about four months between the two amputations.

Flap Amputation at Site of Election.

When a flap amputation is done at the site of election, the skin may be closed by primary suture, delayed primary suture or secondary suture. There is no place for a closed method of amputation in the initial treatment of battle casualties or in the control of infection. This truth has been reverified in the present war, and primary skin suture is now carried out only after a reamputation through clean tissues. In other cases the wound is dressed with sulphonamide powder and the flaps are left for delayed primary or secondary suture, according to whether infection develops.

Sites of Election.

At the chief limb-fitting centre of the Ministry of Pensions in England, 40,000 artificial legs have been fitted since the Great War and over 1,100 have already been supplied during this war. The following statements are quoted from the description by Perkins of the conclusions which have been drawn from this experience:[3]

1. End-bearing stumps do not last. The majority of pensioners of the Great War with Syme and transcondylar amputations—amputations designed to take end-bearing—have required reamputation at a higher level. It should be noted, however, that this conclusion is not accepted by Canadian surgeons, who consider that, in the lower limb, the Syme and Stokes-Gritti amputations are to be preferred to all others. It may be that the Canadian limb-makers produce a better limb than we in this country; the fact remains that the limbs evolved by British limb-makers for amputations at these two levels are unsatisfactory.

2. The shorter the stump, the less trouble it gives. The troubles are mostly circulatory. The end of a long stump becomes cold, blue and congested, and finally ulcerates; and stumps a trifle shorter suffer in proportion to their length.

3. The stump must be long enough to remain within the socket during movement.

4. The stump must be long enough to contain the insertion of the muscles activating the joint above the amputation.

5. The stump must not have a bulbous extremity; otherwise it will not fit inside a conical socket.

In terms of these principles one may discuss the various sites of election above and below the elbow.

Above-Knee Amputations.—The best length for an above-knee stump is ten to twelve inches measured from the top of the great trochanter. If the stump is longer than this, circulatory troubles are likely to occur; if it is shorter two difficulties arise: it is hard to retain the limb inside the socket when the patient flexes his hip, especially as the adductor muscles, which are deprived of most of their bone attachment, tend to bunch up and spoil the even slope of the stump; and, further, the lack of adductor power allows the abductor muscles to hold the artificial leg in slight permanent abduction.

If the stump is so short that it cannot be retained in the socket when the patient flexes his hip, then active hip flexion has to be eliminated and shoulder control used instead. The patient lifts the artificial limb off the floor by rising on the toes of his sound limb. He then shrugs his shoulders and so applies tension to braces which flex the hip on the injured side. The flexor muscles of the stump are therefore not used, and the stump does not tend to leave the socket. This elaborate method is, of course, only relatively successful, and the gait is laboured and awkward.

In certain cases the stump may have to be so short that flexion of the hip is not possible even by the shoulder brace method. A "tilting-table" prosthesis then has to be used, in which the socket is fitted half-way round the pelvis. Weight-bearing is efficient because the ischium sits in the bucket, but control of the extremity depends entirely on movement of the pelvis. The chief fear of the patient is that the leg will fall off, and, therefore, the more bony points to which the socket can be fitted, the better.[1] If the amputation can be made just below the lesser trochanter, the ilio-psoas flexes the stump, and the greater trochanter and the end of the femur form two bony points useful to the limb-maker.

Below-Knee Amputation.—The best length for the stump in a below-knee amputation is five and a half inches, measured from the joint line on the medial side to the end of the tibia. The fibula should be half an inch shorter than the tibia to prevent bony union and resultant pain at the stump end. The muscles controlling movement of the knee joints are inserted into the first couple of inches of the tibia, but, unless at least a length of four inches is retained, the stump does not remain in the socket when the knee flexes. An extra inch and a half is useful because the amputation is difficult to perform satisfactorily; a wide, poorly nourished scar may result and require plastic resection. It is no longer believed, however, that the ideal below-knee stump should be seven inches long; with advancing years the patient is unable to maintain the blood supply for such a long stump. A further change in the treatment of below-knee amputations is that, in an increasing number of cases, the weight of the body is being transmitted through the ischial tuberosity.[5] Formerly the weight was borne by the expanded upper end of the tibia and the head of the fibula; this caused painful bursæ to develop. When the amputation is satisfactory and the limb correctly fitted, it is not possible to detect that a man is wearing a prosthesis.

Below-Elbow Amputation.—The best length for the stump below the elbow is seven inches, measured from the tip of the olecranon to the end of the ulna. The radius should be half an inch shorter than the ulna, so that there will not be cross union between the two bones, leading to an expansion at the end of the stump. It is impossible to retain movements of pronation and supination, because, even if the radio-ulnar joint is preserved, these movements

are prevented by the constriction of the socket. A socket loose enough to permit rotation is too loose to fit the stump.

A long forearm stump would have an adequate blood supply, but when a shorter stump is used, the appliances controlling the movements of the artificial hand can be brought nearer to the elbow and are more easily manipulated. The stump is not retained in its socket if the length is less than four inches.

Above-Elbow Amputation.—The best length for the stump above the elbow is eight inches, measured from the point of the acromion process to the end of the humerus. This length is sufficient to maintain the stump well in the socket, but leaves room for the fitting of an artificial elbow at the natural level. Moreover, it does not include the expanded lower portion of the humerus. If a terminal expansion is present it is impossible to use a conical metal socket, and the arm can be fitted only by a leather socket which is laced at the side. Such a socket is inefficient and uncomfortable.

This survey of recent English literature shows then, that the ideal sites for amputation are as follows:[1] (*a*) above the knee, eleven inches from the greater trochanter; (*b*) below the knee, five and a half inches from the line of the knee joint; (*c*) above the elbow, eight inches from the acromion process; and (*d*) below the elbow, seven inches from the tip of the olecranon. Of the remaining amputations, the modified Syme has been recently discussed in most detail.[2] Some of the disagreement between the two schools in regard to this amputation is resolved when one remembers that the operation is difficult to do well, but has to be well done to give an efficient stump. The flaps have to be cut so that there is no redundant tissue, and it is essential that the flap which comes from the heel should be fixed firmly over the severed tibia and fibula, and should not be displaced during the three weeks after the operation. The operation fails if even mild infection occurs or if the blood supply of the flaps is inadequate.

The status of the operation is not yet finally decided. It is now admitted that the Canadians have practised it successfully; this may be partly due to the special attention they have given to the requirements of the operation, and partly to the success of their limb-makers in developing a satisfactory prosthesis. All surgeons are agreed that the Syme amputation should not often be done on women, for the artificial limb does not look well. It is also accepted that the operation should be done only when infection of the stump is unlikely to occur.

Technique of Flap Amputations.

Situation of the Scar.[3]—When end-bearing was practised it was important not to have a terminal scar, and the flaps were therefore made unequal. In the modern artificial limb the stump does not make contact with the socket, and a terminal scar is an advantage. Equal antero-posterior flaps may be fashioned for each of the four main amputations described; when unequal flaps are used the blood supply to the longer one may fail. Too much skin should not be left, for intertrigo is caused by redundant folds.

It is important to obtain a non-adherent scar. A certain amount of movement of the scar occurs, and, if the scar is attached to muscle, this movement is communicated to the soft tissues and neuromata, and is therefore painful. It follows that a scar adherent to bone is less troublesome than one attached to muscle.

Muscles should not be used to cover the end of the bone; otherwise a baggy terminal mass is formed instead of a firm conical stump. Nerves should not be shortened, crushed or injected. Shortening has survived only because of its use in end-bearing amputations; in other circumstances it is illogical. Painful neuromata are probably due to one of three causes: pressure from the socket, traction from an adherent scar, and irritation from fibrous tissue formed in response to maltreatment at operation or in response to infection.

Hæmostasis is very important, since bleeding is often a factor in separating the skin edges, or causing sloughs, or permitting infection, and each of these complications is serious. It is wise to drain the wound if infection is at all likely.

Perkins points out that amputations vary in the ease with which they may be performed: "both of the arm amputations are easy to do and may be relegated to a house surgeon; the above-knee amputation is relatively easy and is well within the compass of a registrar; the below-knee amputation is difficult and should only be done by the expert." When one considers that the below-knee amputation is difficult and specialized, it is easier to understand why there should be argument as to whether it is or is not better than the Syme.

Post-Operative Treatment.

Care of the amputation stump is an important factor in securing a good end result. The posture of the limb should be controlled so that the more powerful flexor muscles are not allowed to cause a flexion deformity; in the past a thigh stump has often been rested on a pillow, with the result that the hip was flexed; if a flexion deformity of the knee or hip lasts for more than a few weeks, it is unlikely that it will ever be cured completely. After the stitches have been taken out exercises should be commenced, and by the end of a month there should be free movement; too early handling may be a factor in causing phantom limb. Massage is inadvisable; it does not reduce the œdema and it irritates the soft tissues.

The shape of the early stump is unsuitable from the point of view of fitting an artificial limb. It has to be converted into a narrow cone. This is best achieved by bandaging with a long *crêpe* bandage in such a way that the stump is compressed most in the distal parts. The bandage must be applied with tension and must be readjusted three or four times during the day.

It is usually possible to fit an artificial leg in about three months from the healing of the wound, and an artificial arm in six weeks, although in each case the socket may become too big as the limb shrinks to its final shape, which is attained in about six months. The patient needs encouragement, especially while waiting for the artificial limb and when trying to learn to walk. A patient who has suffered amputation is acutely aware of his loss and may show symptoms of anxiety or depression. His treatment is not complete until he has been reinstated in employment.

Amputations in Children.

It is customary to withhold proper artificial limbs from children on the ground that the limb soon becomes too small. Normal limb function is so important to the development of the child, however, that expense should not be a sufficient argument against providing a good prosthesis. Children quickly learn to use artificial limbs, and can then behave like their fellows. If unsatisfactory pylons or peg-legs are fitted, the child acquires an unnatural gait which is difficult to alter.

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